A Closer Look

Ozone by EPA Region

The national trends presented so far do not completely describe the ozone story. Because weather patterns and emission changes are variable throughout the United States, it is important to examine ozone trends on a more detailed basis, such as regionally. This initial regional assessment focuses on monitored levels of 8-hour ozone by EPA Region. One-hour ozone levels show similar patterns.

Not surprisingly, a closer look at trends in measured ozone values by EPA Region shows differences in the progress made since 1980 in different parts of the country. Although all Regions have experienced reductions in ozone concentrations, some have made more substantial advances than others. For example, EPA Regions 1, 9, and 10 exhibited the most significant improvement in ozone (20%, 37%, and 22% decreases, respectively), as shown in Figure 14. In general, the greatest improvements occurred in areas that had the highest ozone concentrations back in the early 1980s. EPA Regions 2 and 5 exhibited the least improvement (11% decreases).

Ozone trends in EPA Regions since 1990 (Figure 15) show patterns similar to the 1980 trends. However, progress in reducing ozone concentrations has slowed nationally since 1990. Again, the Northeast (Region 1) and the southern West Coast (Region 9) show the most progress. Areas in the western portion of the country (Regions 7 and 8) showed the least improvement over the past 14 years.

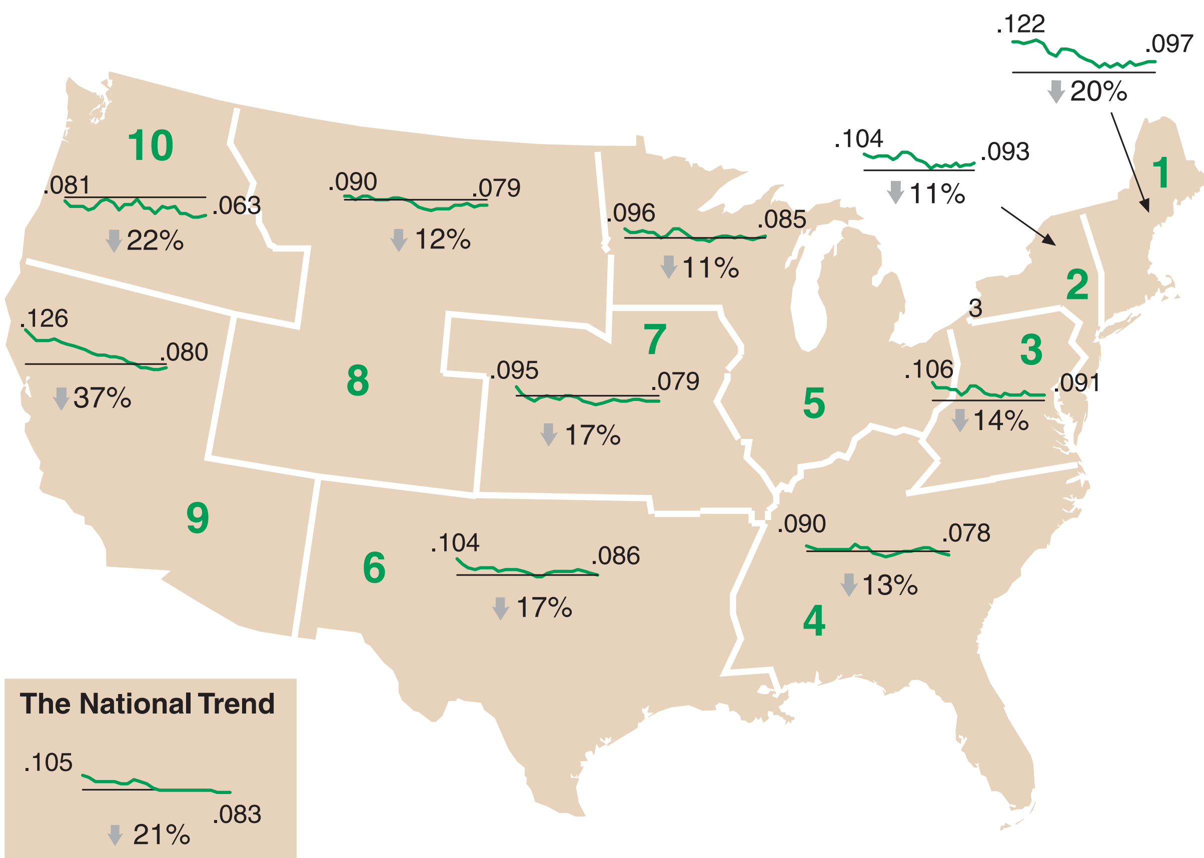

Figure 14. Trend in Fourth Highest Daily Maximum 8-Hour Ozone Concentration (ppm) by EPA Region, 1980–2003.

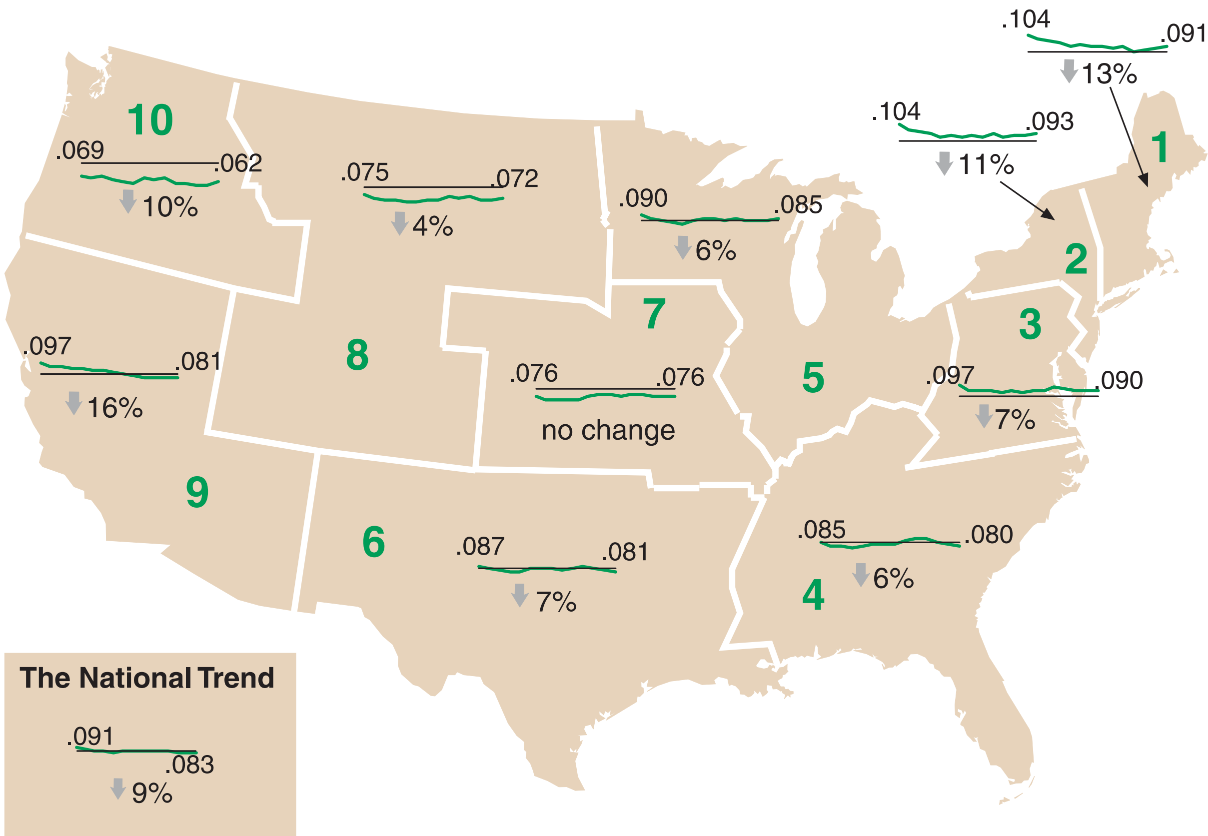

Figure 15. Trend in Fourth Highest Daily Maximum 8-Hour Ozone Concentration (ppm) by EPA Region, 1990–2003.

Although trends by EPA Region provide important insights into different rates of improvement across the country, even these depictions mask interesting differences in air quality at more local levels. For example, the significant downward trend in EPA Region 9 (16% decrease) is largely influenced by the improvements in Los Angeles and other southern California metropolitan areas where VOC and NO_x emission control programs have had significant impact on ozone concentrations. In other urban areas within Region 9, ozone improvements have been more modest or even different directionally, as illustrated in Figure 16. The concept of looking at trends for a more localized area than EPA Regions is explored further in "A New Look at Patterns in Ozone Trends" on page 15.

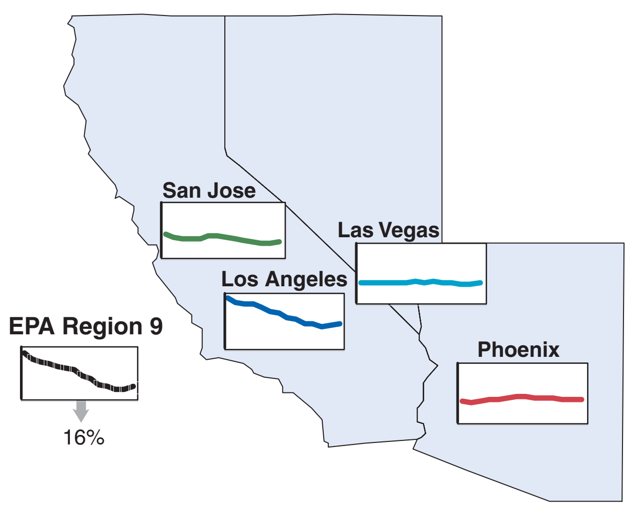

Figure 16. Difference in Trends in Fourth Highest Daily Maximum 8-Hour Ozone Concentrations for Metropolitan Areas in Region 9, 1990–2003.

Meteorological Adjustment

Ozone is formed through complex chemical reactions of VOC and NO_x emissions during periods of conducive weather conditions. Ozone is more readily formed when it is sunny and hot and the air is stagnant. Conversely, ozone production is more limited when it is cloudy, cool, rainy, and windy. For these reasons, ozone concentrations are generally the highest during the summer.

To separate the effects of weather from those of VOC and NO_x emissions, measured ozone levels can be adjusted to account for the impact of meteorology. This meteorological adjustment technique helps us understand how much of the year-to-year variability of an ozone trend is due to the weather rather than to the effects of emission control programs.

The number of summertime days above 90° is one of the indicators of conditions conducive to ozone formation. Figure 17 shows temperature data together with the meteorologically adjusted trends (1990–2003) for two example metropolitan areas. For these eastern cities, the meteorological adjustment generally lowers the measured ozone when the summer is relatively hot. Similarly, when the summer is cool, the adjusted value is usually increased. For Atlanta, you can see these adjustments for the hot summer of 1993 (where the meteorologically adjusted value is lower) and the cool summer of 2003 (where the adjusted ozone value is higher). These graphics help explain how meteorologically adjusted trends smooth out some of the year-to-year variability in observed ozone levels.

Figure 18 presents trends in meteorologically adjusted ozone levels by EPA Region from 1990 to 2003. These results are based on summertime average daily maximum 8-hour ozone and meteorological data for 35 selected eastern cities. (At the time of publication, meteorologically adjusted data for western cities were not available.) With these analyses, we can begin to look at some of the influence of meteorology on ozone. However, these analyses are based on a limited number of cities in each EPA Region, so these regional trends should not be compared directly to the regional trends presented in the previous section. Before adjusting for weather, EPA Regions 3, 4, and 6 show improving air quality, with average reductions in ozone levels of 9% to 21%. After adjusting for weather, however, each Region demonstrates a more moderate decline. The most dramatic effect of the meteorological adjustment is in Region 4, where the adjusted trend shows a 4% decrease, compared with a 21% decrease for the unadjusted trend. Region 6 shows the largest improvement, 9%, after adjusting for meteorology. Ozone levels in the midwest and central regions of the country show the same percent increase in ozone both with and without the meteorological adjustment. EPA Region 2 shows a larger increase in ozone levels after the meteorological adjustment is applied.

The current meteorological adjustment method does not reflect all of the influences of meteorology on ozone. For example, future analyses will try to better account for year-to-year variations in ozone levels due to regional transport.

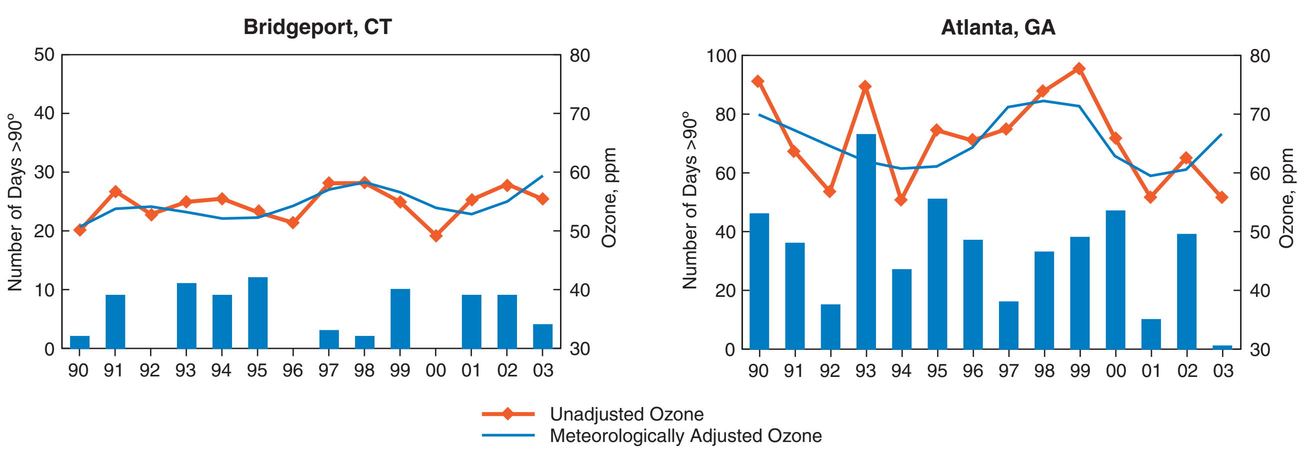

Figure 17. Number of Days Daily Maximum Temperatures Exceed 90° (bar) Compared to Unadjusted Ozone (red line) and Meteorologically Adjusted Ozone (blue line) for Bridgeport and Atlanta, 1990–2003. Ozone Concentrations are Annual Average Daily Maximum 8-Hour Values between June and August.

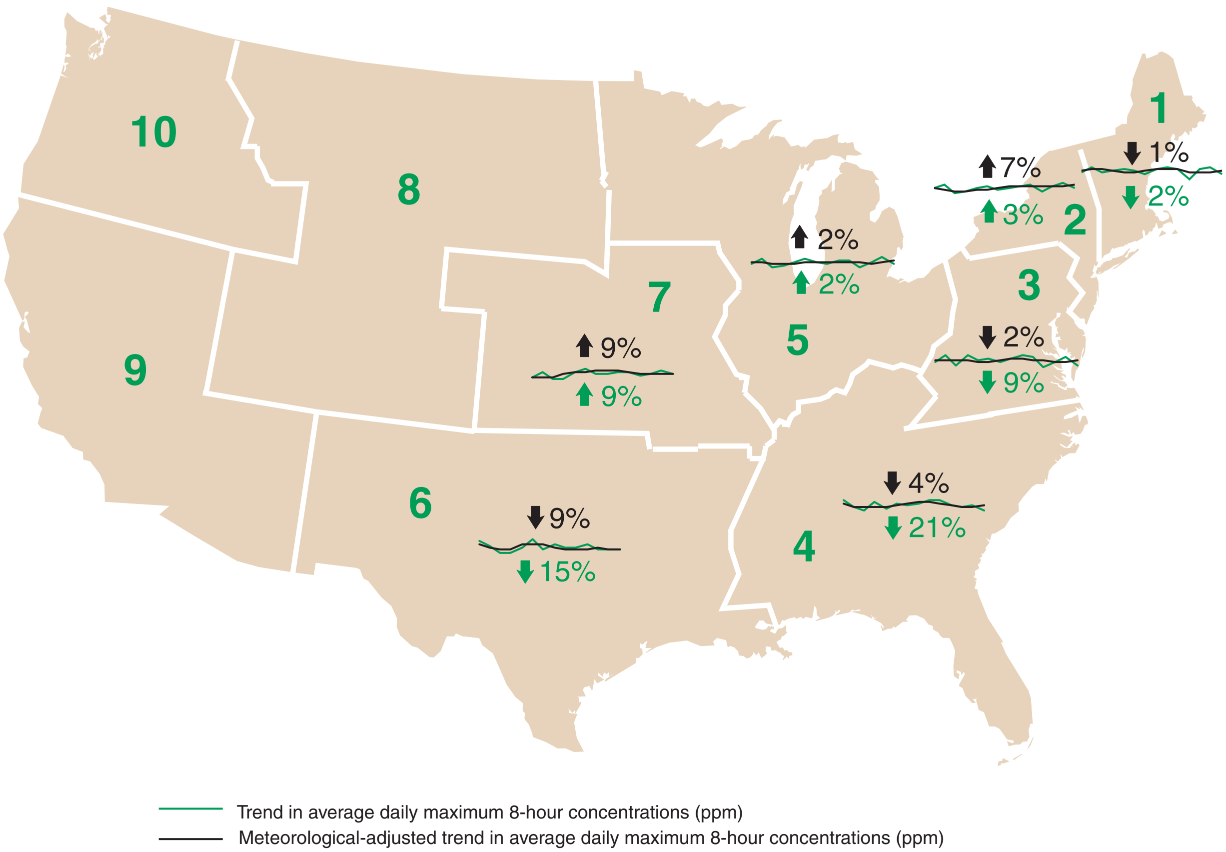

Figure 18. Trends in Unadjusted and Meteorologically Adjusted Ozone Levels by EPA Region, 1990–2003.

Emission Trends by EPA Region

We can now look at regional trends in VOC and NO_x emissions and make an initial comparison to the meteorologically adjusted regional ozone trends described previously. Regional emissions data are currently available only since 1996 and are presented in Figure 19. The declines over the past 7 years are substantial. Regional VOC reductions varied from 11% to 27%. Regional NO_x reductions varied from 14% to 25%. The largest reductions for VOCs and NO_x occurred in Regions 3, 4, and 5, which account for more than half of the national decrease.

Improvements in ozone air quality in the eastern United States since the mid-1990s generally coincide with these VOC and NO_x emission reductions. Regions 3 and 4, where significant emission reductions occurred, also show progress in reducing ozone levels. This is even more evident when the second half of the 14-year ozone trend is examined. The apparent absence of an associated ozone air quality improvement in Region 5 may be due at least in part to the location of the emission sources. Much of the NO_x emission reductions occurred at facilities located in the Ohio Valley. Most of Region 5's metropolitan areas are upwind of these emission sources. However, emission reductions would be expected in downwind areas because pollutants can be transported hundreds of miles.

Regional emission reductions conform to phased implementation of emission control programs during the late 1990s, as described at the national level. For example, relatively large NO_x reductions occurred in the Mid-Atlantic and Midwestern states (Regions 2, 3, and 5) during 1999 and in the Southeast (Region 4) during 2000. These reductions correspond to implementation of the Acid Rain Program, as described earlier. Several eastern Regions also had large NO_x reductions in 2003, which may be attributed in part to implementation of the Ozone Transport Commission's NO_x Program and the NO_x State Implementation Plan (SIP) Call.

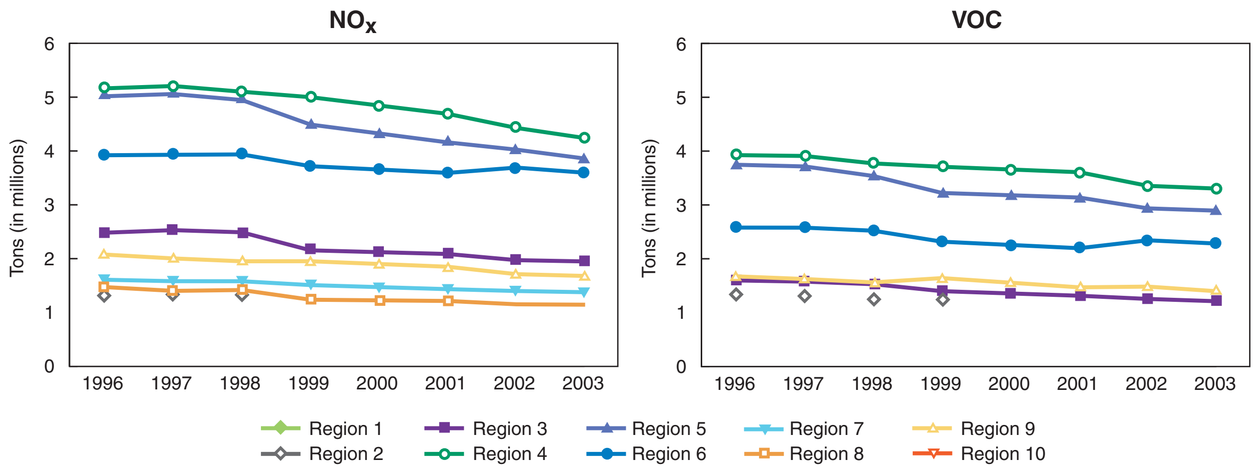

Figure 19. NO_x and VOC Emissions by EPA Region, 1996–2003.

Note: *The large increase in VOC emissions in Region 10 from 1998 to 1999 is due to a change in methodology rather than a true emission increase.*

A New Look at Patterns in Ozone Trends

It is important to understand ozone trends as they relate to NO_x and VOC emission trends to properly design programs to mitigate ozone and to assess the nation's progress in reducing ozone. However, the influence of weather makes it difficult to isolate the specific changes in ozone concentrations that result from VOC and NO_x reductions. In addition, and as previously indicated, assessing trends in ozone levels nationally or by EPA Region may mask important local differences that make it difficult to determine direct influence of emission reductions. We begin to address these factors by looking at meteorologically adjusted ozone trends for selected metropolitan statistical areas (MSAs) in the East. The results provide some interesting patterns that may be useful in defining regions of similar ozone concentration behavior. Studying these regional patterns may lead to insights into the underlying effects of changes in emission levels and transport of emissions on ozone air quality. A full explanation of this analysis of ozone patterns can be found at **www.epa.gov/airtrends/ozonepatterns.html**.

These patterns have two characteristics: the overall direction of MSA ozone trends (i.e., increases, no change, or decreases) and the shape of each trend's pattern (i.e., when temporary increases or decreases occur). Consistency in these patterns suggests that groups of MSAs behave similarly, showing several geographic clusters with consistent ozone trends. For example, the trends across many eastern MSAs reveal an overall improvement in ozone levels since 1990 and a temporary increase in ozone levels during the mid-1990s, followed by decreases in ozone levels beginning in 1998. The improvement in ozone levels in the late 1990s coincides with reductions in NO_x emissions associated with the Acid Rain Program. Figure 20 shows reductions in NO_x emissions for the states contributing most of the reductions in NO_x since 1996. The figure also shows the coincidental decrease in meteorologically adjusted ozone levels across three of the identified geographic clusters. The NO_x reductions occurred across many of the midwestern states, with the ozone trends downwind reflecting the transport of ozone precursors. At the same time, NO_x and VOC reductions occurred from mobile sources, which also influence ozone concentrations. Further analysis is needed to sort out the degree of influence from regional and local sources of ozone precursors.

Although additional investigation and more complete characterization of meteorological influences are needed, these relatively consistent regional patterns in the behavior of ozone may, after further study, offer important insights into designing programs to reduce ozone and to assess the nation's progress in that direction. First, the approach appears to define areas with "similar" ozone behavior and thereby provide a meaningful grouping of urban areas. Further, with improved information on emissions on a more refined geographic and temporal scale, these data-defined regions may enhance our ability to understand and explain changes in ozone concentrations in terms of regional transport, varying meteorology, and changes in emissions.

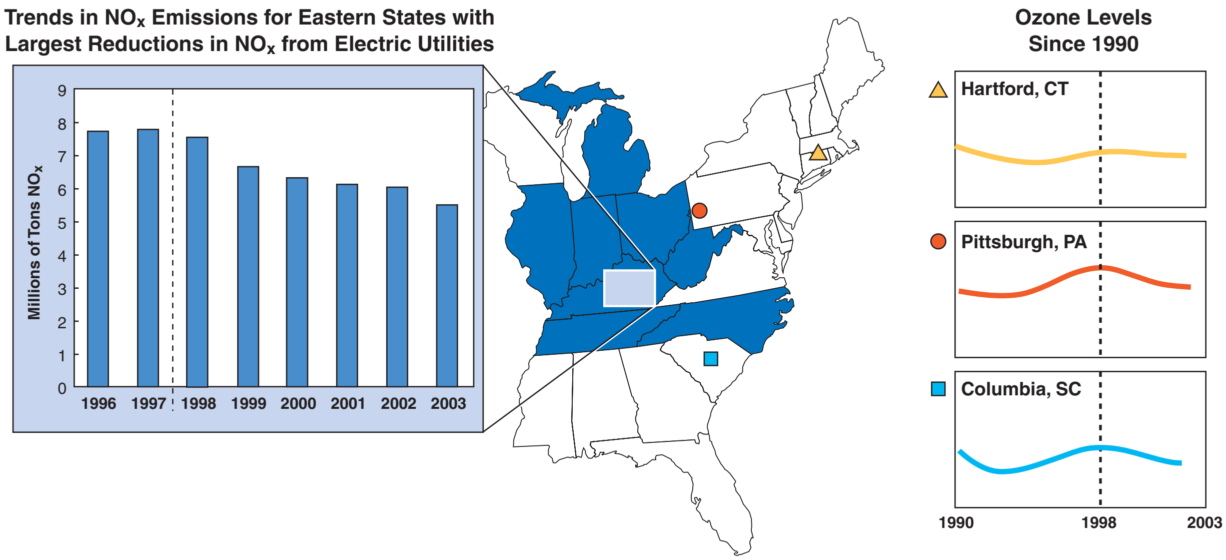

Figure 20. Ozone Trends for Selected Urban Areas and Corresponding Regional Emission Trends.

Note: *Visit* www.epa.gov/airtrends/ozonepatterns.html *to look at additional areas with regional patterns of similar ozone trends.*

National Parks and Other Federal Lands

Thirty-two national parks and federal lands located outside urban areas, mostly in the western United States, had sufficient monitoring data to assess trends for the period 1990–2003. Most of the locations show no net change in 8-hour ozone levels over this time period. Levels at four locations increased slightly between 1990 and 2003, while levels at four other locations decreased slightly. No location has shown significant improvement over the past 14 years. Six locations experienced statistically significant increases in ozone during this period: Great Smoky Mountains (Tennessee) in the eastern United States and Mesa Verde (Colorado), Rocky Mountain (Colorado), Craters of the Moon (Idaho), Canyonlands (Utah), and Yellowstone (Wyoming) in the West. Generally, the locations with the most consistent and pronounced upward trends are located in the West, where the last two summers have been warmer and drier than average. In contrast, the locations showing the largest improvements in ozone levels are found in the East, where the summer of 2003 was cooler and wetter than normal. The obvious exception is the Great Smoky Mountains National Park, for which a significant upward trend has already been noted. As Figure 21 illustrates, however, the overall trend at Great Smoky Mountain National Park is driven by an increase in ozone levels in the late 1990s, which has been followed by consistent improvement over the past several years.

Ozone trends for many national parks and federal lands in the East and South are similar to those of nearby urban areas, providing evidence of the regional nature of the ozone problem. For example, as seen in Figure 21, the federal land in South Carolina (Cape Romain) reveals declining ozone levels since 1990 and a temporary increase late in the period consistent with the trends in the neighboring urban area (Columbia, South Carolina). In addition, the ozone trend in Brigantine, New Jersey, reflects the same direction and pattern seen in the Mid-Atlantic region for areas such as Philadelphia and Baltimore, whereas the trend in Cape Cod mirrors those of New York and Hartford. Knoxville, Nashville, and Great Smoky Mountains National Park all show similar trends in ozone for the period 1990–2003. Comparisons between national parks and nearby urban areas are more readily performed in the East and South, where physical proximity between the two makes associations more meaningful. Further exploration is needed to assess trends and patterns in western rural areas.